FULFILLMENT OF EVENT-BASED INTENTIONS CAN BE MULTIPLY DETERMINED

by

JUSTIN B. KNIGHT

(Under the Direction of Richard L. Marsh)

ABSTRACT

Event-based prospective memory (PM) refers to the cognitive processes that enable completion of intentions by relying on some environmental cue. There is an ongoing debate as to whether attentional processes are always needed in order to notice intention-related cues. Using dense-array electroencephalography, we sought to examine this issue by evoking a visual steady-state response (SSVEP) while participants performed a lexical decision task with a PM intention. Two groups of participants were either given the intention to make a special key press when they saw the word *horse* or when they saw any *animal* word. Attentional modulation of SSVEPs revealed differential reliance on attentional processes between the groups. Analysis of event-related potentials revealed further dissociations between the two types of intentions. These results suggest that different processes can subserve the detection of cues required for fulfilling intentions.

INDEX WORDS: Prospective memory, Steady state visual evoked potential (SSVEP), Attention, Event-related potential (ERP),

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FULFILLMENT OF EVENT-BASED INTENTIONS CAN BE MULTIPLY DETERMINED

Introduction

When an intended action or behavior is delayed because it cannot be executed at the current time, one must rely on the strategic use of attention and memory to perform that action in the future. The broad ranging field of research concerned with understanding the cognitive, affective, social, and neural mechanisms that support such “memory for the future” is termed prospective memory (PM). Examples of prospective memories include remembering to maintenance one’s vehicle (e.g., getting the oil changed) or remembering to deliver a message to a colleague. The strategy of relying on environmental cues to remind one to fulfill such delayed intentions (e.g., the mechanic shop in the above example) is referred to as event-based prospective memory. An open question of debate centers on whether these intention-related cues can trigger the intention automatically or whether engagement of attentional processes must always be used to notice cues (Einstein & McDaniel, in press; Scullin, McDaniel, & Einstein, 2010; Smith et al., 2007; Einstein et al., 2005; Smith et al., 2003). Thus far, behavioral investigation of this question has produced equivocal results (Einstein et al., 2005, Smith & Bayen 2005, Hicks, Marsh, & Cook, 2005). The current study sought to capitalize on the sensitivity of steady-state visual evoked potentials (SSVEP) to the engagement of attention in order to examine the attentional processes relied upon to notice two different types of intention-related cues.

In typical event-based laboratory experiments, participants are engaged in some ongoing task (e.g., deciding whether a string of letters is a word or a nonword) while also possessing an intention to make a special key press when they encounter a certain word (e.g., *horse*) or one of any words from a certain set (e.g., words from the category *animals*). The ongoing task is meant to simulate everyday activities that one would be engaged in during the delay between forming an intention and the opportunity for completing the intention. With either intention cues occur on a small proportion of trials (usually 10% or less). The proportion of cues that receives a special key press serves as a behavioral metric for assessing successful PM performance.

The successful fulfillment of prospective memories is dependent on two components: prospective and retrospective memory processes (Einstein & McDaniel, 1996). The prospective component refers to remembering that you have an intention to be fulfilled. Thus, realizing that the event-based cue is associated to a previously-formed intention relies on the prospective component. The retrospective component refers to the recollection of the intended behavior and when it needs to be executed (Smith & Bayen, 2004; Marsh, Cook, & Hicks, 2006). Both components are integral to the successful completion of prospective memories; however, we were primarily concerned here with the prospective component.

Existing theories of event-based prospective memory have opposing assumptions about the processes that can subserve the prospective component (i.e., noticing of intention-related cues). The Preparatory Attentional and Memory processes (PAM) theory assumes that attentional processes must *always* be used in order for cues to be noticed as relevant to a delayed intention (Smith et al., 2007; Smith & Bayen, 2005; Smith & Bayen, 2004; Smith, 2003). By contrast, the Multiprocess View (MPV) predicts that cues can in some cases be noticed automatically (Einstein et al., 2010; Einstein et al., 2005; McDaniel & Einstein, 2000). Specifically, the MPV proposes cues can be noticed in the absence of preparatory attentional processes (a) if the processing of the task focuses one on the relevant features of the cue, (b) if the cue is salient, or (c) if a strong association is formed between the cue and the target action (Einstein & McDaniel, 2005; Scullin, McDaniel, and Einstein, 2009). If none of these stipulations are met, then MPV asserts that preparatory attentional processes will be needed to notice cues. Preparatory attentional processes are thought to be engaged across the task to support a readiness to process incoming stimuli as potential cues. These processes can operate by monitoring the environment for opportunities to execute the intention and potentially function through mapping the features of the current stimulus onto those that constitute a cue (Smith et al., 2007; Knight, Ethridge, Clementz, & Marsh, 2010).

In sum, these preparatory processes reflect an allocation of attention toward noticing cue occurrences which may result in increased processing of the presented stimuli (Guynn, 2003; Knight et al., 2010). The additional processing is capacity consuming and is typically reflected in slowed responding to the ongoing task when an intention is embedded relative to when completing the ongoing task alone. This slowed responding is referred to as task interference (Marsh, Hicks, Cook, Hansen, & Pallos., 2003; Hicks, Marsh, & Cook, 2005). Task interference has, for the most part, been used as the standard dependent variable to assess the presence or absence of preparatory attentional processes and thus to compare the predictions of the PAM theory and MPV (Scullin et al., 2010; Smith et al., 2007; Einstein et al. 2005; Marsh et al., 2005; Smith, 2003, Marsh et al., 2003). Simply, task interference should be present if participants were relying on some attentional processes to notice cues (Smith et al., 2007; Hicks et al., 2005; Smith, 2003; cf. Einstein & McDaniel, in press). If task interference is not present, then participants likely were allocating little to no attentional processes toward noticing cues. Across a number of studies that have sought to disambiguate the PAM theory from MPV the results are mixed as to whether task interference is found (Scullin et al., 2010; Knight et al., 2010; Smith et al., 2007; Einstein et al., 2005; Hicks et al, 2005; Smith & Bayen, 2004). These equivocal results suggest that task interference may not provide a sensitive enough measure for determining the presence or absence of preparatory attentional processes. Thus, in the present study, we sought to supplement typical behavioral measures with electrophysiological indices of attentional processing as measure by dense-array EEG.

A steady-state visual evoked potential (SSVEP) paradigm was used to provide a continuous measure of attention across the task (Di Russo, Teder-Salejarvi, & Hillyard, 2002). The SSVEP is a neural oscillatory response at the driving frequency of a flickering visual stimulus (Regan, 1989). SSVEPs have reliably been found to be modulated by the engagement of a wide range of attentional and cognitive processes including spatial selective attention (Morgan, Hansen, & Hillyard, 1996; Muller & Hillyard, 2000), feature selective attention (Muller et al., 2006), sustained attention (Clementz, Wang, & Keil, 2008), covert attention (Belmonte & Todd, 2003), mental rotation (Wilson & O'Donnell, 1986), and working memory (Ellis, Siberstein, & Nathan, 2006). The SSVEP amplitude, or strength of the response, is increased for attended relative to unattended stimuli (Morgan et al., 1996), and the synchronization of the oscillatory response with the stimulus flicker is facilitated by attention (Kim, Grabowecky, Paller, Muthu, & Suzuki, 2007). That is, attention causes the SSVEP to be more time-locked with the flickering stimulus. The neural generators of the SSVEP have been localized to the medial occipital cortex (V1) and ventral-lateral occipital cortex (extrastriate cortex; Di Russo, et al., 2007; Fawcett et al., 2004) with the attentional modulation of the SSVEP being largely generated by the ventral-occipital cortex (Hillyard et al., 1997; Belmonte & Todd, 2003).

Research examining the neural mechanisms that support attentional processes in prospective memory is still in its infancy. Burgess and colleagues have proposed key roles for the anterior prefrontal cortex and the parietal cortex in supporting preparatory attentional processes (Burgess, Qualye, & Frith, 2001; Simons, Scholvinck, Gilbert, Frith, & Burgess, 2006). The involvement of these regions coincides with proposals of a fronto-parietal network that subserves attentional control across a number of tasks (Burgess et al., 2003; Cabeza et al., 2003). Additionally, modulations of event-related potentials (ERPs) over frontal and parietal-occipital regions beginning around 400 ms post-stimulus have been associated with attentional processes devoted toward noticing prospective cues (West, Bowry, & Krompinger, 2006; West, McNerney, & Travers, 2007). Previous research examining the neural correlates of preparatory attentional processing, however, has not sought to directly test opposing predictions derived from the PAM theory and MPV.

In addition to investigating the neural underpinnings that support preparatory processes in service of noticing cues, we were also interested in examining the neural mechanisms that operate at the actual presentation of the cue. Previous studies have reported an enhanced negativity over the occipital-parietal region maximal around 300 ms post-stimulus that is greater for noticed cues than both missed cues and ongoing task stimuli (West & Krompinger, 2005; West & Wymbs, 2004; Bisiacchi, Schiff, Ciccola, & Kliegel, 2009). This negative potential, termed the N300, has been associated with noticing a cue as relevant to a delayed intention. The N300 has been proposed to be dependent on preparatory attentional processes because the N300 was diminished when preparatory attentional processes were not engaged (West, 2007). The diminished N300, however, was found during contexts when participants were instructed to ignore the cue, and thus, the intention was not active. We were interested in examining whether a similar relationship between preparatory attention and the N300 would be observed when the intention was active.

Between two groups, which both completed two phases of a word-nonword judgment task (one with an embedded prospective intention and one without), we varied the type of cue that was associated with the intended action of making a special key press. The intention-related cue for one group was a single word (i.e., *horse*) which could be focally processed during the task; Einstein & McDaniel, 2005; Hicks et al., 2005; Scullin et al., 2009). The cue for the other group was any word from the category of animals, thus the actual cues could not be processed at encoding (Hicks et al., 2005). Proponents of both the PAM theory and MPV agree that preparatory attentional processes would be needed to notice categorical cues (Einstein & McDaniel, 2005; Smith, 2003). However, with regard to the specific cue, MPV assumes that such a cue could be noticed automatically, whereas the PAM theory predicts that preparatory attentional processes should still be evident across the task (Smith et al., 2007; Einstein et al., 2005). Using the sensitivity of the SSVEP to attention, we sought to assess if comparisons of the oscillatory response when participants were completing the task with an embedded intention relative to completing the task alone would differ between groups. Converging evidence from response latencies and ERPs will also address these questions.

CHAPTER 2

Materials and Methods

Participants

Twenty-four healthy right-handed participants (age range: 18-22; 13 females) were recruited from the University of Georgia undergraduate student population. Participants received course credit to partially fulfill a research appreciation requirement. Participants provided informed consent, displayed no signs of neurological impairment, were free of psychiatric and substance-abuse disorders (self-report), and had normal or corrected-to-normal vision. This study was approved by the University of Georgia Institutional Review Board.

Stimuli

Stimuli were presented using Presentation experimental software on a 21” high resolution monitor (60 Hz refresh rate) with participants seated 70 cm away. A four-button response pad was used to collect finger press responses to stimulus events. Each trial began with a small white fixation square on the screen. This fixation point remained on the screen for 250 ms then a luminance modulated (100% modulation depth) white rectangle flickering at 15 Hz was presented over the square for 3000 ms. The fixation square was then removed, the flickering rectangle remained and a luminance modulated linguistic stimulus flicking at 15 Hz was superimposed on the rectangle. Both the rectangle and linguistic stimulus flickered in phase for 1500 ms. The screen was then blank for 1500 ms to allow for settling of the SSVEP neural generators (Clementz et al., 2004). All stimuli were presented against a dark backround (.1 cd./m^2 background). The linguistic stimuli were either words, nonwords, or cues. All words and cues were acquired from the Kučera and Francis (1967) compendium and had a medium to high frequency of occurrence, three to nine letters, and one to three syllables. Nonwords were acquired from the same database, but one to three letters were changed to create pronounceable nonwords.

EEG Recording

EEG data were recorded vertex-referenced using a 256-sensor Geodesic Sensor Net and NetAmps 200 amplifiers (Electrical Geodesics; EGI, Eugene, OR). The sensor net was adjusted until all pedestals were properly seated on the scalp (i.e., not sitting on thick mats of hair that could result in bridging between sensors, e.g., Greischar et al., 2004). Individual sensor impedances were adjusted until they were below 50 kΩ (Ferree, Luu, Russell, & Tucker, 2001). In addition, an electrolyte bridge test was conducted between all pairs of sensors prior to recording (Tenke & Kayser, 2001), and, if there was evidence of bridging, sensors were adjusted until bridging was no longer evident (this was rarely required). Data were sampled at 500 Hz with an analog filter bandpass of 0.1–200 Hz. A Macintosh G4 running EGI's Netstation software was used for data collection.

Procedure

Participants were randomly assigned to one of two conditions which differed only in regard to the type of cue that was associated with the intention. The behavioral task consisted of two phases of lexical decision tasks (LDT): a baseline LDT and an LDT with an embedded intention. The order in which these two LDTs were completed was counterbalanced across participants for both conditions. On each trial in the baseline LDT, participants made judgments as to whether a string of letters that was presented on the screen comprised a valid English word or not. Participants were encouraged to make their judgments as quickly and accurately as possible. Participants' judgments were recorded using a four-response keypad that was situated comfortably in their lap. They were told to press the "1" key with their left index finger if the presented stimulus was not a word and to press the "4" key with their right index finger if the presented stimulus was a word. The baseline LDT consisted of 150 trials (75 word trials and 75 nonword trials). Words and nonwords, in both LDTs, were randomly presented.

The LDT with an embedded intention (henceforth referred to as the PM task) consisted of 400 trials which included 160 word trials, 200 nonword trials, and 40 cue trials. In line with previous studies (Smith 2003; Smith & Bayen 2004), cue trials comprised 10 percent of the total trials and were presented every 10th trial. Presenting cues at regular intervals across trials is typical in studies of event-based prospective memory (Smith 2003; Marsh et al., 2003; Marsh et al., 2006; Brewer et al., in press). The type of intention that participants were given was manipulated between conditions. Participants in the specific PM condition received an intention that was associated to a single word (i.e., the word *horse*).They were told that if they ever encountered the word *horse* during the PM task, then they should press the "3" key with their right index finger, instead of the "4" key. Participants in the categorical PM condition received an intention associated with a semantic category (i.e., animal words). The intended action (i.e., pressing the "3" key) was the same in the categorical condition and the specific condition; however, those in the categorical condition were told to make a special response if they ever encountered a word that named an animal during the PM task (e.g., the word *tiger*). Thus, the event-based cue could be any animal word, and 40 different animal words were presented. The PM instructions were delivered at the time the LDT with an imbedded intention was to be completed. After receiving PM instructions, participants completed a 2 minute distractor task (i.e., a maze task) before beginning the PM task. Participants were given a short break in between the baseline and PM task as well as half way through the PM task.

Behavioral Analysis

Prospective memory performance for both conditions was operationalized as the proportion of cues that received a “3” key response. As in previous published reports, only word trials were included in analysis of task interference (Brewer, Knight, Unsworth, & Marsh, 2010; Marsh et al., 2006; Hicks et al., 2005). Nonword response latencies have been found to be largely insensitive to the engagement of preparatory attentional processes, likely because intentions are typically associated with words and nonwords are irrelevant to the intention (Marsh et al., 2003). Moreover, nonword processing involves a late rejection component that extends beyond valid word processing (Braun et al., 2006). Though examining linguistic differences in word and nonword processing is interesting in its own right, all analyses comparing the baseline task to the PM task will include only word trials. We eliminated non-cue word latency trials that fell beyond 2.5 standard deviations from a given participant’s mean for the baseline and PM tasks. We also eliminated all trials in which an incorrect lexical decision was made. Both procedures resulted in a total loss of 4.5% of the data, and excluding these data did not change any of the results reported here. Task interference was analyzed in a 2 (Lexical Decision Task: Baseline vs. PM) × 2 (Condition) mixed-model ANOVA.

EEG Data Processing

Sensors around the neck and cheeks were excluded from analysis, leaving 211 sensors. Data were then pre-processed following recommendations (with minimal modification) made by Junghofer, Elbert, Tucker, and Rockstroh (2000). Raw data were visually inspected offline for bad sensor recordings. Bad sensors were interpolated (no more than 5% of sensors for any subject) using a spherical spline interpolation method as implemented in BESA 5.1 (MEGIS Software, Gräfelfing, Germany). Data were transformed to an average reference and digitally filtered from 1-50 Hz (6 db/octave rolloff, zero-phase). Artifact correction was achieved by using the Independent Component Analysis (ICA) toolbox in EEGLAB 4.515 (Delorme & Makeig, 2004) running under Matlab (Version 7.0, MathWorks, Natick, MA). ICA allows artifact removal without spatially distorting the data by using higher-order statistics to produce temporally independent signals in the data (Onton, Westerfield, Townsend, & Makeig, 2006). Independent components with topographies representing saccades, blinks, and heart rate artifact were removed according to published guidelines (Jung et al., 2000). Brain activity was quantified using two approaches. A spectral measure was used to SSVEP differences between the two conditions. Additionally, ERP measures were used to assess differences in amplitude and spatial distribution of the event-related activity elicited by words and cues between the two conditions.

SSVEP Analysis

Previous studies have found that SSVEP amplitude and phase alignment (degree of across-trial phase similarity between brain activity and the flickering stimulus) are both sensitive to attentional manipulations (Morgan et al., 1996; Kim et al., 2007). Thus, in the present study we quantified the SSVEP using grand average power which provides a measure of the amplitude of the phase aligned electrocortical activity across time. Grand average power of the oscillatory response across time was estimated by complex demodulation at the flickering rate (15 Hz) for the average activity evoked across trials, for word and cue trials separately (Regan, 1989). Complex demodulation allows for quantification of time-dependent changes in power at a particular frequency of interest. This procedure essentially filters out all other frequencies expect the frequency selected (Draganova, & Popivanov, 1999). Data were multiplied with 15 Hz sine and cosine functions. A Butterworth zero-phase low pass filter of 1 Hz was applied to the resulting time series before obtaining the vector length of the sine and cosine parts as a measure of time-varying averaged power (Clementz et al., in press). The narrow low pass filter provides optimal frequency resolution to separate out the activity at the specific driving frequency. Mean SSVEP power was obtained for an epoch spanning from 500 ms prior to 5000 ms after steady-state onset for each sensor, trial type, and subject. Because measured EEG signals vary widely across people, we standardized the resulting complex demodulated mean waveforms for each participant. SSVEP power across time at each sensor was *z*-transformed for each participant and trial type based on the average power and standard deviation of all sensors, time points, and trial types for a given participant (Clementz et al., in press; Kim, et al., 2007).

EEG data from 70 sensors over the posterior scalp that captured the SSVEP were used for analysis of oscillatory activity (Clementz et al., in press; Clementz et al., 2008). Averages were then computed for both conditions' baseline and PM task trial types. Four epoch averages were obtained for statistical analysis of power across time. The four epochs consisted of the mean power for the 500 ms pre-flicker, mean power of the 3000 ms epoch when the flickering rectangle was presented, mean power of the 1500 ms epoch when the flickering rectangle and linguistic stimuli were presented, and mean power of the 500 ms epoch following steady-state offset. Differences in power across time for words were assessed in a mixed-model ANOVA that tested a between groups factor of condition (specific, categorical) and within-groups factors of task (baseline, PM) and epoch (pre-flicker, flicker, flicker & stimulus, ITI). Differences in power across time for cues were assessed in a mixed-model ANOVA that tested a between groups factor of condition (specific, categorical) and a within-group factor of epoch (pre-flicker, flicker, flicker & stimulus, ITI).

Topographical distributions of SSVEP power were plotted for baseline words and PM words and cues. In order to assess differences in the topographical location of the oscillatory response, we computed the scalp *x*, *y*, and *z* coordinate locations with the maximum grand average power for each participant, trial type, and task. Averages of each coordinate location for all trial types and tasks were then obtained for both conditions. The locations with maximum power are plotted as 3D ellipsoids which represent the mean and standard error of the scalp locations (Yvert, Crouzeix, Bertrand, Preisler, & Pantev, 2001). Separate paired t-tests were computed for each coordinate location to compare both groups' baseline word scalp location to their respective PM word scalp location. Independent t-tests were computed for each coordinate location to compare specific PM words to categorical PM words.

A multiple source beamformer computation, as implemented in BESA (Hoechstetter, et al., 2004), was used to localize the primary neural generator of the 15 Hz activity for the specific and categorical PM words. Beamformers can be used to localize a specific range of activity in the time-frequency domain. After EEG data for each electrode were transformed into the time-frequency domain (1 Hz/40 ms resolution), the 15 Hz (± .5 Hz) activity for the first 750 ms of each word trial was extracted for each participant using a complex cross spectral density estimation (Gross et al., 2001). A 15 Hz power estimate, representing the amplitude and phase of the activity, was derived for each voxel, trial, and participant (slice: 4.5 mm, voxel: 4.5x4.5x4.5 mm). This power was then normalized to the power in the 750 ms baseline epoch preceding each trial, resulting in a ratio of the word epoch power to baseline power. Before source solutions were fit, a realistic head model was constructed based on a four shell ellipsoidal model (Berg & Scherg, 1994). The brain, CSF, skull, and scalp constitute the four homogeneous shells. The spherical shells were warped into an ellipsoid that best fit the 3D electrode coordinates for each participant. Standard conductivities were estimated for the brain, CSF, skull, and scalp (.33, 1, .0042, .33). Source solutions were obtained by local peaks in the normalized-power. Importantly, multiple source beamformers take into account highly-correlated sources when estimating source activity which protects against mislocalization of bilateral sources to a medial region. Independent t-tests were run at each voxel to compare differences in source solutions between the specific and categorical PM words. Significant cluster size was determined based on Monte Carlo simulations calculated using AlphaSim (Cox, 1996). To maintain the alpha lower than .05, fourteen neighboring voxels with effects significant at $p < .05$ were required.

Event-related Potential Analysis

The EEG Data were digitally filtered from 1-10 Hz (12 dB/octave rolloff) for ERP analysis. The 10 Hz low-pass filter was used to avoid confusion of the ERPs with the initiation of the 15 Hz SSVEP (Clementz et al., in press). Grand average ERP waveforms were then obtained for baseline words and PM words and cues. Epochs were 2000 ms long, which included 500 ms pre-stimulus and the 1500 ms linguistic stimulus presentation. Baseline correction was conducted using the 500 ms pre-stimulus interval. The goal of the first ERP analysis was to examine differential effects the two types of intentions might have on ongoing task processing. Thus, this analysis was aimed at determining if the ERP components reveal any differential effects between conditions due to attentional processing when completing the task with an intention. ERP components of interest were determined based on previous findings and visual inspection of the data. Previous findings have reported that effects of preparatory attentional processes are primarily evident in modulations of late components (i.e., beyond 400 ms post-stimulus) over the occipital-parietal region (with the inverse of the dipole evident over the frontal region as well; Bisiacchi et al., 2009; West et al., 2007; West et al, 2006). Analyses were carried out on the ERP mean amplitude from 600-800 ms post-stimulus. Clusters of seven sensors over the left and right parietal-occipital region (surrounding P3 and P4 on standard 10-20 system) were used to calculate the mean amplitudes. ERP differences were assessed with a mixed-model ANOVA that tested a between-groups factor of condition (specific, categorical) and within-subject factors of task (baseline, PM) and hemisphere (left, right).

Additionally, we were interested in how cue processing may differ between the specific and categorical intentions. Separate ERP waveforms were constructed for PM words and cues for both conditions. Analysis of the N300, associated with noticing cues, was examined using the mean amplitude from 200-350 ms over the occipital-parietal region (West and Krompinger, 2005). Clusters of eight sensors over the left and right occipital-parietal region (surrounding P7 and P8 on standard 10-20 system) were used to calculate the mean amplitudes. ERP effects were assessed with a mixed-model ANOVA that tested a between-groups factor of condition (specific, categorical) and trial type (word, cue), and hemisphere (left, right). Considering that semantic processing has been found to effect ERP components evident over the frontal region around 400 ms post-stimulus (Franklin et al., 2007; Nobre & McCarthy, 1994), we sought to examine if differences in this component would dissociate cue processing between the two types of intentions. Clusters of seven sensors over the left and right frontal region (surrounding F3 and F4 on standard 10-20 system) were used to calculate the mean amplitudes. ERP effects were assessed with a mixed-model ANOVA that tested a between-groups factor of condition (specific, categorical) and trial type (word, cue), and hemisphere (left, right).

CHAPTER 3

Results and Discussion

Initial analyses were conducted to examine effects of counterbalancing, and no such effects were apparent in the data. For all analyses reported, the data for the baseline LDTs that were completed first and last were pooled together, separately for each condition. The same pooling was done for the PM tasks.

Behavioral Data

The specific condition detected significantly more cues than the categorical condition $t(22) = 4.25$, $p < .001$, $d = 1.73$, replicating previous results that specific cues (M = .94, SE = .01) are more readily detected than categorical cues (M = .83, SE = .02; Hicks et al., 2005; Marsh et al., 2003). Accuracy on the ongoing task was high across both conditions and tasks (at or above 96%). Analysis of mean response latencies revealed a main effect of task $F(1, 22) = 57.53$, $p < .001$, $\eta^2_p = .72$, but the main effect of condition failed to reach significance $F(1, 22) = .21$, $p = .65$. Critically, the interaction was significant $F(1, 22) = 19.519$, $p < .001$, $\eta^2_p = .47$. This interaction reflected the finding that latencies were significantly slower in the PM task as compared with the baseline task for the categorical condition (Base: M = 692.14, SE = 34.76; PM: M = 827.35, SE = 34.05) $t(11) = -10.99$, $p < .001$, $d = 1.13$, but not for the specific condition (Base: M = 718.54, SE = 37. 21; PM: M = 754.22, SE = 41.02) $t(11) = -1.89$, $p = .085$. These results suggest that participants in the categorical condition were engaging capacity consuming preparatory attentional processes to notice cues in the PM task whereas the statistically equivalent response latencies in the baseline and PM tasks for the specific condition suggest participants in this condition did not recruit additional attentional processes in the PM task. These findings replicate previous research (Hicks et al., 2005; Marsh et al., 2003)[1].

SSVEP Data

Analysis of grand average power across time revealed a main effect of epoch $F(1,22) = 57.19$, $p < .001$, $\eta^2_p = .722$, such that power much higher when the flickering stimuli were on the screen relative to when the screen was blank (Figure 3.1). No other differences emerged between the tasks or conditions when analyzing grand average power for words across the four epoch means (largest $F(1,22) = 2.6$). In the analysis of grand average power for cues the same effect of epoch was present $F(1,22) = 38.73$, $p < .001$, $\eta^2_p = .638$ (Figure 3.1). This analysis produced no other significant effects or interactions (largest $F(1,22) = 2.6$).

A difference emerged in analysis of the scalp location where grand average power was maximal for words (Figure 3.2). Categorical and specific PM words significantly differed along the *z*-coordinate axis $t(22) = 2.29$, $p =.032$, $d = .94$. Along the *x*-coordinate and *y*-coordinate axes, categorical and specific PM words did not differ (largest $t(22) = .64$). Baseline words did not differ between conditions along any of the coordinate axes (largest $t(22) = 1.66$). Also, baseline words did not differ from PM words along any of the coordinate axes for either condition (largest $t(22) = 1.73$). The difference in scalp location between PM conditions revealed that the maximum oscillatory response was more inferior for categorical PM words relative to specific PM words. Beamformer source analysis revealed a significant cluster in the ventral-lateral occipital cortex that exhibited more extreme power for the categorical PM words relative to the specific PM words (Figure 3.2). Thus, the source analysis corroborates the scalp differences and suggests that the categorical PM words' SSVEP was generated by a more ventral source as compared with the specific PM words. Analysis of the location where grand average power was maximal for cues reveal no differences between conditions along any of the three coordinate axes (largest $t(22) = 1.24$). Therefore, Beamformer source analysis was not carried out on these items.

ERP Data

Examining baseline and PM word differences for the two condition between the 600-800 ms epoch averaged over the left and right parietal regions revealed a main effect of hemisphere $F(1,22) = 9.24$, $p = .006$, $\eta^2_p = .30$, and a marginal task by condition interaction $F(1,22) = 3.43$, $p = .078$, $\eta^2_p = .135$. No other effects or interactions approached significance (largest $F(1,22) = 2.49$). As expected, because the task was language-related, the left hemisphere exhibited the most dominant response. The marginal interaction reflects the trend for word amplitude to be more extreme in the PM task relative to the baseline for the categorical condition but not for the specific condition (Figure 3.3). This trend may reflect reliance on preparatory attentional processes to notice cues in the categorical PM task and an absence of reliance on such processes in the specific PM task. Previous studies have reported similar late modulations of ongoing task stimuli reflective of preparatory processes (West et al., 2007; West et al., 2006). The marginal interaction here may have failed to reach conventional levels of significance due to a lack of power (only had .43 power to detect a significant task by condition interaction). Planned comparisons examining differences in amplitude (averaged over left and right hemisphere) between tasks for both conditions support this notion, as word amplitude was found to be significantly more extreme for the categorical PM task versus its baseline $t(11) = -2.24$, $p =.047$, $d = .37$., but not for the specific PM task versus its baseline $t(11) < 1$.

Analysis of the N300 revealed main effects of trial type $F(1,22) = 8.89$, $p = .007$, $\eta^2_p = .288$, and hemisphere $F(1,22) = 10.46$, $p = .004$, $\eta^2_p = .322$, which were qualified by a significant trial type by hemisphere interaction *F*(1,22) = 5.30, $p = .031$, $\eta^2_p = .194$, and a trial type by hemisphere by condition interaction *F*(1,22) = 6.47, $p = .019$, $\eta^2_p = .227$. No other significant effects or interactions were found (largest *F*(1,22) = 1.86). Planned comparisons were conducted to examine the higher-order three way interaction. These comparisons revealed that specific PM cues elicited a more extreme voltage over the left occipital-parietal region than specific PM words *t*(11) = 3.8 , $p =.003$, $d = .74$., whereas mean amplitude for categorical PM cues and words did not differ *t*(11) < 1 (Figure 3.4). Thus, a clear N300 was found for the specific PM cues but not for the categorical PM cues. The N300 has been associated with the prospective component of noticing cues.

Analysis of the anterior positivity revealed a main effect of hemisphere *F*(1,22) = 14.70, $p = .001$, $\eta^2_p = .401$, that was qualified by a trial type by hemisphere by condition interaction *F*(1,22) = 10.34, $p = .004$, $\eta^2_p = .320$. All other effects and interactions were nonsignificant (largest *F*(1,22) = 1.45). Again the effect was left lateralized, and the left frontal voltage for specific PM cues was less extreme than that of specific PM words. However, categorical PM cues elicited a more extreme voltage than categorical PM words over the left frontal region (Figure 3.4). This dissociation of ERPs elicited by cues between the two conditions may represent a repetition effect for specific cues (Misra & Holcomb, 2003) and a semantic expectancy effect for categorical cues (Franklin et al., 2007). Considering this is the first epoch during which categorical cues were dissociated from categorical words, this ERP effect may support noticing of categorical cues.

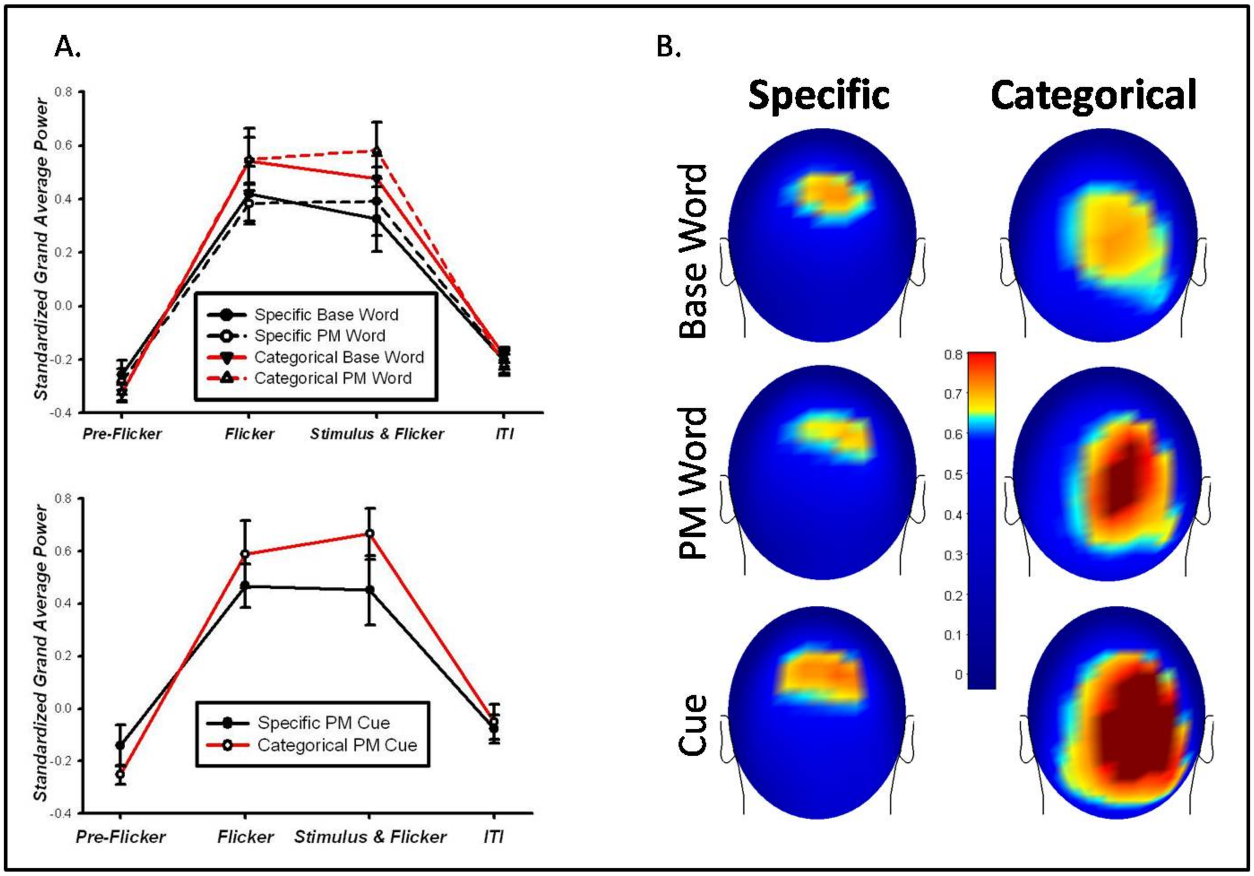

Figure 3.1 **Grand Average Power Amplitude and Topography** A. Standardized grand average power plots for specific baseline and PM words and categorical baseline and PM words (top), and specific and categorical cues (bottom). Pre-flicker represents the mean of the 500 ms epoch before the flickering stimulus appears. Flicker represents the mean of the 3000 ms epoch when the flickering box is on the screen. Stimulus & Flicker represents the mean of the 1500 ms epoch when the flickering box and linguistic stimulus are on the screen. ITI represents the mean of the first 500 ms epoch of the inter-trial interval when the screen is blank. B. Standardized grand average power topographies for both conditions' baseline words and PM words and cues.

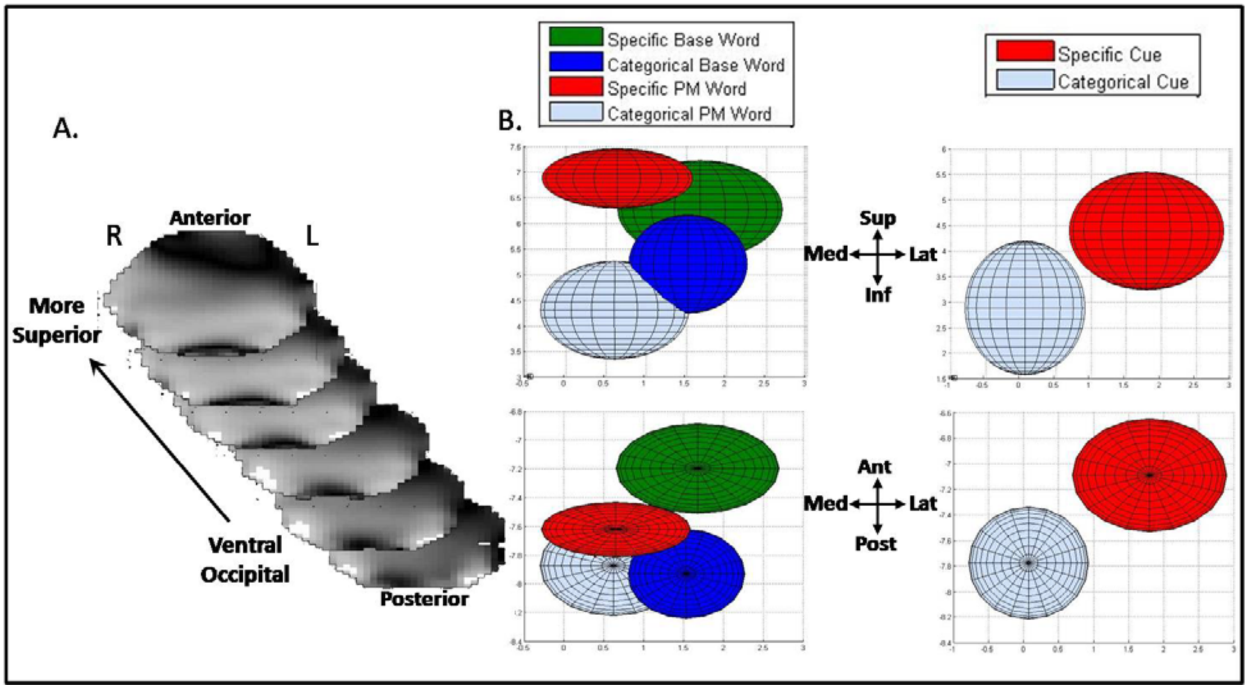

Figure 3.2 **Location of Maximal Grand Average Power** A. Axial brain slices (4 mm thick) depicting t-values derived from a comparison of specific and categorical PM words. The t-test was computed on the solutions obtained from the Beamformer source analysis. Slices are presented in radiological convention with the right side of the brain on the left, and vice versa. The bottom slice is of the most inferior region of the occipital cortex (just above the cerebellum). Voxels with significant t-values are white. A significant cluster was found over the right ventral-lateral occipital region. B. Ellipsoid standard error plots of specific baseline and PM words and categorical baseline and PM words (first column), and specific and categorical cues (second column). Ellipsoids represent the mean scalp coordinate (cm) location where grand average power was maximal for each trial type. The first row of plots are plotted in relation to the *x*-coordinate axis (ranging from medial to right lateral on the scalp) and the *z*-coordinate axis (ranging from inferior to superior on the scalp). The second row plots are plotted in relation to the X-coordinate axis (ranging from medial to right lateral on the scalp) and the *y*-coordinate axis (ranging from posterior to anterior on the scalp). Sup = Superior, Inf = Inferior, Med = Medial, Lat = Right Lateral, Ant = Anterior, Post = Posterior.

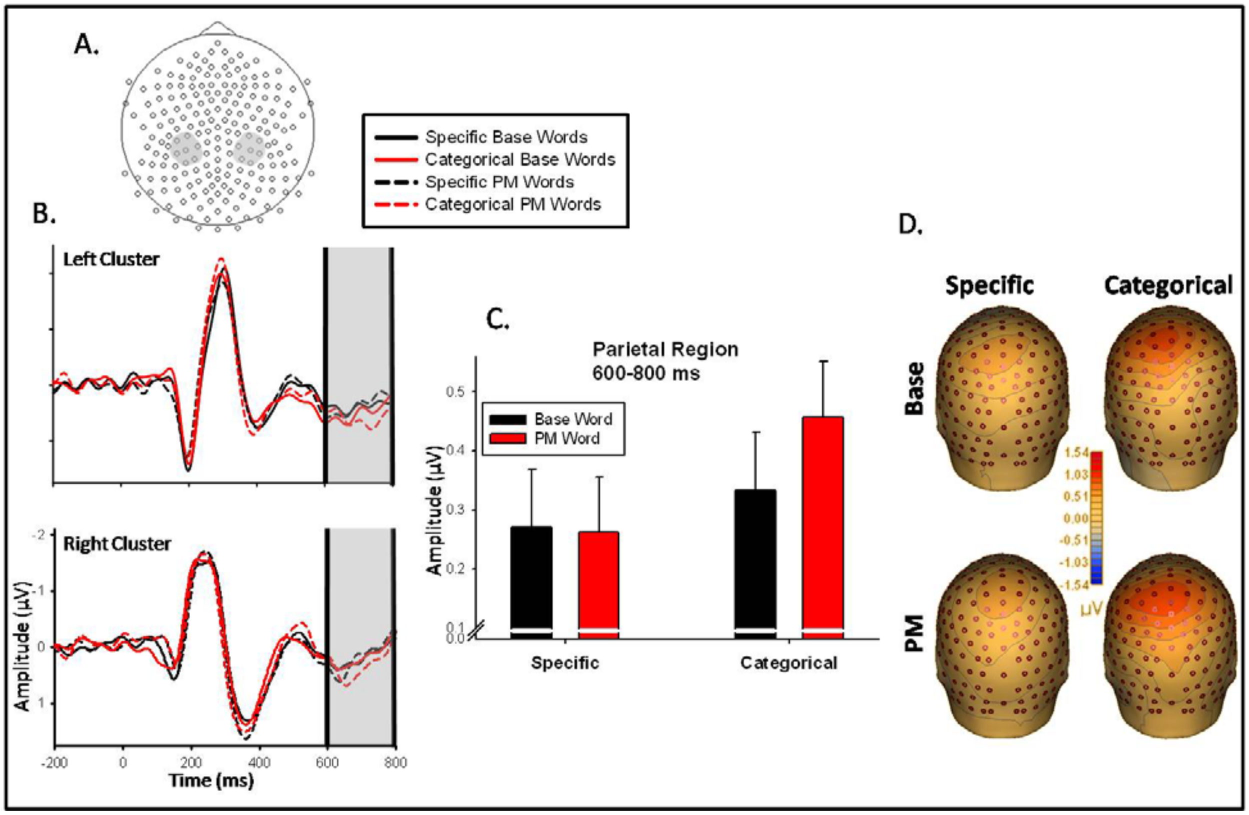

Figure 3.3 **ERP Effect of Preparatory Attention** A. Sensor clusters over left and right parietal regions (surrounding P3 and P4) which were averaged to obtain waveforms and mean amplitudes for the baseline vs. PM ERP comparison. B. ERP waveforms of left and right parietal clusters for specific baseline and PM words and categorical baseline and PM words. C. Mean amplitude from 600-800 ms post-stimulus averaged over both parietal clusters for specific baseline and PM words and categorical baseline and PM words. This plot depicts the marginal task by condition interaction that was driven by the more extreme amplitude for categorical PM words. D. Voltage topographies at 700 ms post-stimulus (the center of the epoch) for specific baseline and PM words and categorical baseline and PM words.

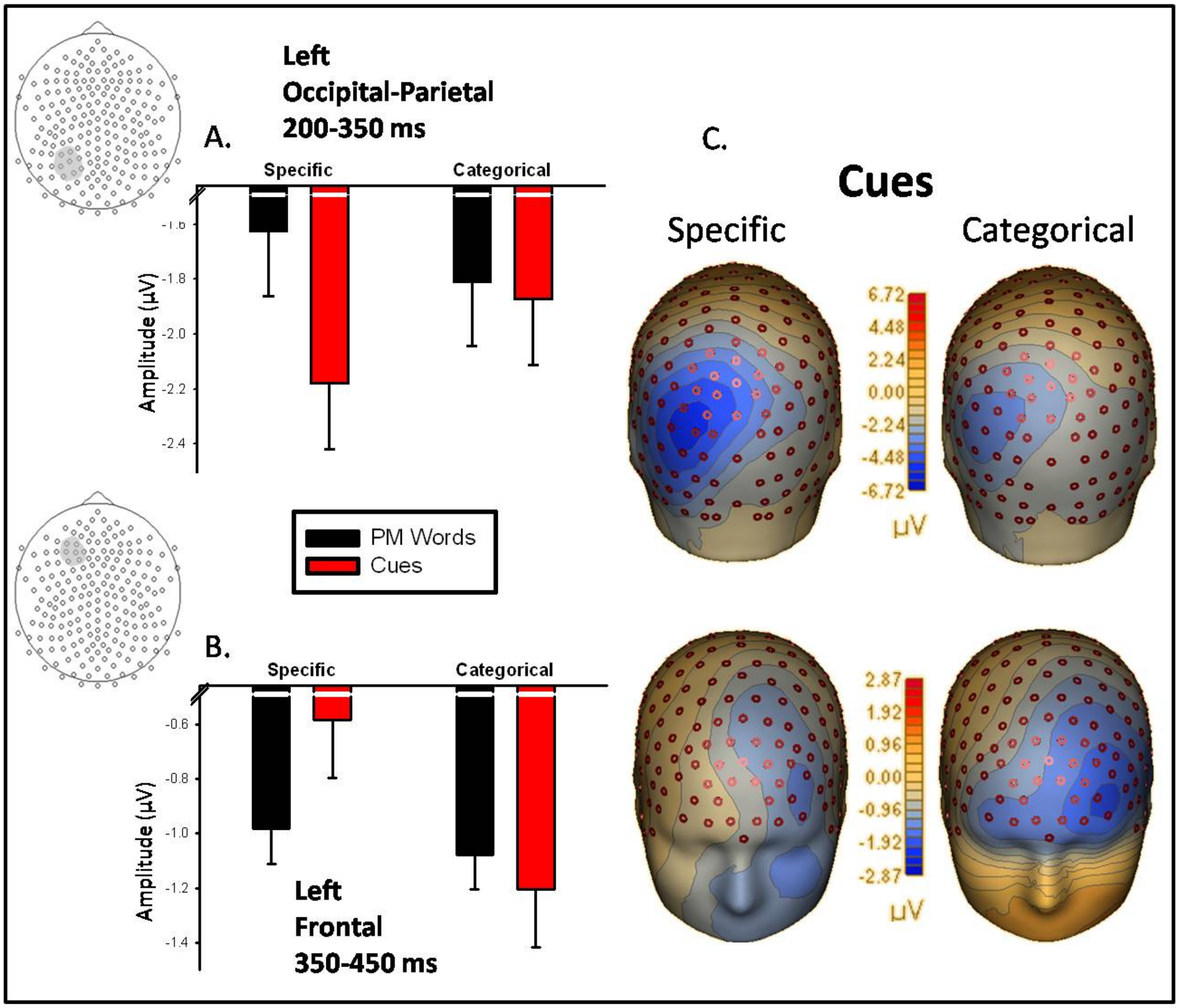

Figure 3.4 **Cue Noticing** A. Mean amplitude from 200-350 ms post-stimulus obtained from the highlighted sensor cluster over the left occipital-parietal region for specific PM words and cues and categorical PM words and cues. This plot depicts the mean amplitude for the N300. B. Mean amplitude from 350-450 ms post-stimulus obtained from the highlighted sensor cluster over the left frontal region for specific PM words and cues and categorical PM words and cues. This plot depicts the mean amplitude for the anterior negativity. C. Voltage topographies obtained from the peak of activity for the N300 (first row) and the anterior negativity (second row), for specific PM cues and categorical PM cues.

CHAPTER 4

General Discussion

Competing predictions of the PAM theory and MPV with regard to the attentional processes required to notice event-based cues were tested. No differences between the two PM tasks relative to their baseline tasks (or each other) in the grand average power of the SSVEP across the tasks were found. However, the results revealed a shift in the location of the oscillatory response that was only present during the categorical PM task, suggestive of an attentional modulation of the SSVEP. ERP analysis revealed a late positive modulation for ongoing trial words in the categorical PM task that was not evident in the categorical baseline task or in the specific condition. These differences support the behavioral findings and potentially suggest that preparatory attentional processes were relied upon to notice cues in the categorical PM task but not the specific. Further dissociation between the two types of intentions was found in the ERPs elicited by the specific and categorical cues. Taken together, these findings support the notion that multiple processes were relied upon to notice event-based cues which favors the predictions made by the Multiprocess View.

The behavioral results are in line with the MPV and replicate previous studies investigating delayed intentions associated with specific and categorical cues (Marsh et al., 2003; Hicks et al., 2005). Specific cues were successfully responded to more often than categorical cues. Importantly, mean word response latencies were significantly slower in the categorical PM task relative to that group’s baseline task whereas mean response latencies did not differ between the specific PM and baseline tasks. Thus, task interference was present in the categorical but not the specific PM task. Consequently, participants in the categorical group appear to be relying on capacity consuming attentional processes to notice cues during the PM task but such was not the case with a specific intention. When seeking to elucidate ectrophysiological mechanisms associated with preparatory attentional processes, it is important to demonstrate that the two groups in the current tasks differed in the degree to which they relied on preparatory processes, and the behavioral results provide such evidence.

In analysis of grand average power, we did not find clear amplification of the SSVEP for either PM task in comparisons to their respective baseline tasks. In typical selective attention SSVEP paradigms, the SSVEP is amplified for attended stimuli relative to unattended stimuli (Morgan et al., 1996). The failure to find a difference here between the PM and baseline tasks may result from the fact that some degree of attention would still be required in the baseline task in order to process whether the stimuli was a word or nonword. Thus, the contrast in processing between the PM and baseline tasks may not have been powerful enough. This same logic may explain why the location of the grand average power maximum did not differ in comparisons of both groups' PM task to their respective baseline task. Nevertheless, a clear dissociation emerged between the categorical and specific PM tasks in regard to the location of the maximum oscillatory response. Both groups' maximal response was recorded medial and posterior on the scalp. However, the two groups differed in that during the specific PM task the maximal response was located superiorly over the parietal-occipital region, whereas the location was more inferior during the categorical PM task. Source analysis of the oscillatory activity at the driving frequency (i.e., 15 Hz) confirmed these scalp differences by revealing that oscillatory activity was more extreme in the right ventral-lateral occipital cortex during the categorical PM task relative to the specific PM task.

In a combined EEG and fMRI study implementing a covert selective attention task, Hillyard et al., (1997) presented bilateral flickering stimuli with superimposed letters or numbers presented on them. For part of the task, participants were to covertly attend to the cued location and detect infrequent targets, while in another part they passively maintained central fixation at a location that was not flickering. In comparisons to the passive trials for both the attend-left and attend-right trials they found amplified SSVEPs in the right ventral-lateral occipital region (the attend-right comparison also showed some contralateral activation, though consistent across the two attend conditions was the activity over the right occipital region). These differences were localized to the extrastriate cortex. The scalp topographies exhibited a right lateralized maxima strikingly similar to the scalp topography elicited during the categorical PM task in the present study. The scalp topography and source localizations were attributed to attentional modulation of the SSVEP in which visual processing in the extrastriate cortex was facilitated. This SSVEP attention effect has been replicated across multiple studies (Belmonte, 1998; Muller et al., 1998; Belmonte & Yurgelun-Todd, 2003). Additionally, activation in the extrastriate/ventral occipital region has been associated with categorical processing in categorization tasks (Fize, Boulanouar, Chatel, Ranjeva, Fabre-Thorpe, & Thorpe, 2000; Martin-Loeches, Hinojosa, Gomez-Jarabo, & Rubia, 2001). Thus, increased SSVEP in the extrastriate cortex found on word trials in the categorical PM task could reflect facilitated categorical processing in order to notice occurrences of the animal cues.

Furthermore, modulation of activity in the ventral-lateral occipital area has been proposed to be driven by a fronto-parietal network that exerts top-down signals to facilitate processing in this occipital area (Corbetta, 1998; Kastner & Ungerleider, 2000; Belmonte & Todd, 2003). The SSVEP source location differences for the categorical PM task relative to the specific are suggestive of the notion that a fronto-parietal control network was engaged across the categorical PM task. Previous studies of PM have implicated the involvement of a fronto-parietal network in supporting preparatory attentional processes (Burgess et al., 2001; Simons et al., 2006; West et al., 2006). Thus, the engagement of preparatory attentional processes in service of noticing cues appears present in the categorical PM task but not in the specific PM task. Further support for this notion stems from the ERP finding of an increase positive amplitude over the parietal region (600-800 ms post-stimulus) for the categorical PM words versus their baseline words as well as versus the specific PM and baseline words. Late positive modulations similar to the one found here have been associated with increased attention devoted toward processing presented stimuli (Azizian & Polich, 2007). In the current study, this late modulation for categorical PM words could reflect a late checking of ongoing trial stimuli to ensure that they were not cues (Guynn, 2003). Consequently the present data suggest that different neural mechanisms were relied upon to notice cues in the two PM tasks, a finding that is more consistent with the MPV than the PAM theory.

Results related to cue processing revealed no differences in grand average power or the location with maximal power between the two cue types. Thus, there was no difference in the amount of attention directed toward specific and categorical cues. However, the mechanism that supported noticing of the two types of cues appears to have differed. The N300, typically associated with noticing cues (West & Wymbs, 2004) was clearly present for the specific cues. The N300 found here was a left lateralized enhanced negativity over the occipital-parietal region between 200-400 ms post-stimulus that differentiated specific PM cues from specific PM words. Previous studies have reported a more right lateralization of the N300 (West & Wymbs, 2004; West et al., 2006). The reason for this discrepancy probably results from the fact that our task was majorly dependent on language processing, whereas most previous studies have used tasks that require less language-related processing (West & Wymbs, 2004; West et al., 2006).

Particularly interesting was the finding that categorical PM cues did not elicit an occipital-parietal negativity that dissociated them from categorical PM words. Instead, categorical PM cues were first dissociated from categorical PM words over the frontal region between 350-450 ms post-stimulus. During this epoch, categorical cues exhibited a more extreme negative voltage relative to their word counterparts. This finding may be similar to studies of semantic priming which have shown that stimuli belonging to the same category that was primed elicit an enhance negativity around 300-400 ms over the frontal region (Franklin et al., 2007; Nobre & McCarthy, 1994). This effect has been associated with semantic expectancy, that is, increased activity resulted because the presented stimulus matched the expected category (Franklin et al., 2007). One cannot be certain that the same semantic processing was involved in the present task; however, it is possible that attentional processes devoted toward noticing animal cues could produce a similar semantic expectancy. Specific cues exhibited a less extreme frontal negativity than specific PM words which is probably due to a repetition effect. Repeated words typically elicit less extreme potentials related to semantic processing (Misra & Holcomb, 2003; Schweinberger, Pickering, Burton, & Kaufmann, 2002). Considering that the N300 dissociated specific PM cues from their word counterparts and the frontal negativity dissociated categorical PM cues from their word counterparts, it appears that different mechanisms supported cue noticing in the two conditions[2]. Moreover, we found specific cues that were noticed clearly elicited an N300 during the task when participant ostensibly were not relying on preparatory attentional processes. Thus, when the intention is active, it appears the N300 is not dependent on the engagement of preparatory processes.

The current results suggest that specific cues may have been noticed by an automatic or spontaneous process (Einstein et al., 2005). When the ongoing task focuses processing on features of the cue (especially those features that were processed at encoding) then the MPV predicts that the prospective component, or noticing of the cue, can occur spontaneously (Einstein et al., 2005; Scullin et al., 2009). This notion follows from the encoding specificity principle which states successful retrieval is dependent on whether features of the item processed at retrieval match those that were processed at encoding (Tulving & Thompson, 1973). The present task focused the participant on processing whole words which matches how the specific cue *horse* was processed at encoding (Einstein & McDaniel, 2005; Scullin et al., 2009). Our data support the assumption that in this situation preparatory attentional processes will not be needed to notice cues. Accordingly, processing of stimuli across a task when one possesses an intention depends on the features of the cues related to that intention (Guynn, 2003; Smith et al., 2007; Knight et al., 2010). When participants had an intention related to cue that was defined by a perceptual attribute (i.e., color), Knight et al., (2010) reported ERP modulations around 140 ms post-stimulus that were associated with the engagement of preparatory attentional processes across the task. This ERP effect was proposed to reflect a facilitation of color processing in order to notice cues. In the present study when the cue was constituted by category membership, the ERP modulation associated with preparatory attention occurred much later (i.e., 600-800 ms post-stimulus). These differential effects suggest that preparatory attention, like selective attention (i.e., Nobre, 2004), is a dynamic process that can operate at different stages of processing depending on the features of the current intention (Smith et al., 2007; Knight et al., 2010).

Future research should examine if a neural signature of preparatory attentional processing that is invariant across different cue types can be found. A potentially promising approach would be to implement the SSVEP paradigm using a number of different intention-related cues. Here we have shown the topographical location and neural generator of the SSVEP shifted when participants were ostensibly relying on preparatory attentional processes. If this same pattern were obtained using a wide variety of cues that required attentional processes to notice, then the SSVEP neural generator could serve a neural index of preparatory attentional processes. Such research would prove useful in future attempts to further examine the validity of the predictions made by the PAM theory and MPV.

REFERENCES

Azizian, A., & Polich, J. (2007). Evidence for attentional gradient in the serial position memory curve from ERPs. *Journal of Cognitive Neuroscience, 19,* 2071-2081.

Belmonte, M. (1998). Shifts of visual spatial attention modulate a steady-state visual evoked potentail. *Cognitive Breain Research, 5,* 294-307.

Belmonte, M. K., & Yurgelun-Todd, D. A. (2003). Anatomic dissociation of selective and suppressive processes in visual attention. *NeuroImage, 19,* 180-189.

Berg, P., & Scherg, M. (1994). A fast method for forward computation of multiple-shell spherical head models. *Electroencephalography Clinical Neurophysiology, 90,* 58-64

Bisiacchi, P. S., Schiff, S., Ciccola, A., & Kliegel, M. (2009). The role of dual-task and task-switch in prospective memory: Behavioural data and neural correlates. *Neuropschologia, 47,* 1362-1373.

Braun, M., Jacobs, A. M., Hahne, A., Ricker, B., Hofmann, M., & Hutzler, F. (2006). Model-generated lexical activity predicts graded ERP amplitudes in lexical decision. *Brain Research, 1073-1074,* 431-439.

Brewer, G. A., Knight, J. B., Unsworth, N. and Marsh, R. L. (2010). Individual differences in event-based prospective memory: evidence for multiple processes supporting cue detection. *Memory & Cognition, 38,* 304-311.

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Neuropsychologia, 39,* 545-555.

Cabeza, R., Dolcos, F., Prince, S. E., Rice, H. J., Weissman, D. H., & Nyberg, L. (2003). Attention-related activity during episodic memory retrieval: A cross-function fMRI study. *Neuropsychologia*, *41*, 390–399.

Clementz, B. A., Gao, Y., McDowell, J. E., Moratti, S., Keedy, S. K., & Sweeney, J. A. (in press). Top-down control of visual sensory processing during an ocular motor response inhibition task. *Psychophysiology*.

Clementz, B. A., Wang, J. & Keil, A. (2008). Normal electrocortical facilitation but abnormal target identification during visual sustained attention in schizophrenia. *Journal of Neuroscience, 28,* 13411-13418.

Corbetta, M. (1998). Frontoparietal cortical networks for directing attention and the eye to visual locations: Identical, independent, or overlapping neural systems? *Proceedings of the National Academy of Sciences of the United States of America, 95,* 831-838.

Cox, R. W. (1996). AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. *Computational Biomedical Research, 29,* 162-173.

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods, 134,* 9-21.

Di Russo, F., Pitzalis, S., Aprile, T., Spitoni, G., Patria, F., Stella, A., Spinelli, D., & Hillyard, S. A. (2007). Spatiotemporal analysis of the cortical sources of the steady-state visual evoked potential. *Human Brain Mapping, 28,* 323-334.

Di Russo F, Teder-Salejarvi WA, Hillyard SA (2002): Steady-state VEP and attentional visual processing. In: A. Zani & A. M. Proverbio (Eds.), *The cognitive electrophysiology of mind and brain* (pp. 259-274). New York: Academic Press.

Draganova, R., & Popivanov, D. (1999). Assessment of EEG frequency dynamics using complex demodulation. *Physiological Research, 48,* 157-165.

Einstein, G. O., & McDaniel, M. A. (2005). Prospective memory: Multiple retrieval processes. Current Directions in *Psychological Science, 14*, 286-290.

Einstein, G. O., & McDaniel, M. A. (2008). Prospective memory and metamemory: The skilled use of basic attentional and memory processes. In A. S. Benjamin & B. Ross (Eds.), *The Psychology of Learning and Motivation* (Vol. 48, pp. 145-173). San Diego, CA: Elsevier.

Einstein, G. O., & McDaniel, M. A. (in press). Prospective memory and what costs do not reveal about retrieval processes: A commentary on Smith, Hunt, McVay, and McConnell (2007). *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

Einstein, G. O., McDaniel, M. A., Thomas, R., Mayfield S., Shank, H., Morrisette, N., & Breneiser, J. (2005). Multiple Processes in Prospective Memory Retrieval: Factors Determining Monitoring versus Spontaneous Retrieval. *Journal of Experimental Psychology: General, 134,* 327-342.

Ellis, K. A., Silberstein, R. B., & Nathan, P. J. (2006). Exploring the temporal dynamics of the spatial working memory n-back task using steady-state visual evoked potentials (SSVEP). *NeuroImage, 31,* 1741-1751.

Ferree, T. C., Luu, P., Russell, G. S., & Tucker, D. M. (2001). Scalp electrode impedance, infection risk, and EEG data quality. *Clinical Neurophysiology, 112,* 536-544.

Fize D., Boulanouar K., Chatel Y., Ranjeva J-P, Fabre-Thorpe M. & Thorpe S.J. (2000). Brain structures involved in rapid categorization of natural scenes: an event-related fMRI study. *Neuroimage, 11*, 634-643.

Franklin, M. S., Dien, J., Neely, J. H., Huber, E., & Waterson, L. D. (2007) Semantic priming modulates the N400, N300, and N400RP. *Clinical Neurophysiology, 118,* 1053-1068.

Greischar, L. L., Burghy, C. A., van Reekum, C. M., Jackson, D. C., Pizzagalli,D. A., Mueller, C., et al. (2004). Effects of electrode density and electrolyte spreading in dense array electroencephalographic recording. *Clinical Neurophysiology, 115,* 710–720.

Gross, J., Kujala, J., Hamalainen, M., Timmermann, L., Schnitzler, A., & Salmelin, R. (2001). Dynamica imaging of coherent sources: studying neural interations in the human brain. *Proceedings of the National Academy of Sciences of the United States of America, 98,* 694–699.

Guynn, M. J., (2003). A two-process model of strategic monitoring in event-based prospective memory: activation/retrieval mode and checking. *International Journal of Psychology, 38,* 245-256.

Hicks, J. L., Marsh, R. L., & Cook, G. I. (2005). Task interference in time-based, event-based, and dual intention prospective memory conditions. *Journal of Memory and Language, 53,* 430–444.

Hillyard, S. A., Hinrichs, H., Tempelmann, C., Morgan, S. T., Hansen, J. C., Scheich, H., & Heinze, H. J. (1997): Combining steady-state visual evoked potentials and fMRI to localize brain activity during selective attention. *Human Brain Mapping, 5,* 287–292.

Hinojosa, J. A., Martı´n-Loeches, M., Mun˜oz, F., Casado, P., Ferna´ndez-Frı´as, C., & Pozo, M. A. (2001). Electrophysiological evidence of a semantic system commonly accesses by animals and tools categories. *Cognitive Brain Research, 12*, 321– 328.

Hoechstetter, K., Bornfleth, H., Weckesser, D., Ille, N., Berg, P., & Scherg M. (2004). BESA source coherence: A new method to study cortical oscillatory coupling. *Brain Topography, 16,* 233-238.

Jung, T. P., Makeig, S., Humphries, C., Lee, T. W., McKeown, M. J., Iragui, V., et al. (2000). Removing electroencephalographic artifacts by blind source separation. *Psychophysiology, 37,* 163-178.

Junghofer, M., Elbert, T., Tucker, D. M., & Rockstroh, B. (2000). Statistical control of artifacts in dense array EEG/MEG studies. *Psychophysiology, 37,* 523-532.

Kastner, S., & Ungerleider, L. G. (2000).. Mechanisms of visual attention in the human cortex. *Annual Review of Neuroscience, 23,* 315-341.

Kim. Y. J., Grabowecky, M., Paller, K. A., Muthu, K., & Suzuki, S. (2007). Attention induces synchronization-based response gain in steady-state visual evoked potentials. *Nature Neuroscience, 10,* 117-125.

Knight J. B., Ethridge L. E., Marsh R. L., and Clementz B. A. (2010). Neural correlates of attentional and mnemonic processing in event-based prospective memory. *Frontiers in Human Neuroscience, 4:5*. doi: 10.3389/neuro.09.005.2010.

Kučera, H., & Francis, W. N. (1967). *Computational Analysis of Present-day American English.* Providence: Brown University Press.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *24,* 336-349.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2005). On the relationship between effort toward an ongoing task and cue detection in event-based prospective memory. *Journal of*

Experimental Psychology: Learning, Memory, and Cognition, 31, 68-75.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2006). Task interference from prospective memories covaries with contextual associations of fulfilling them. *Memory & Cognition*, *34*, 1037-1045.

Marsh, R. L., Hicks, J. L., Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29,* 861-870.

Marsh, R. L., Hicks, J. L., & Watson, V. (2002). The dynamics of intention retrieval and coordination of action in event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 652-659.

Martı´n-Loeches, M., Hinojosa, J. A., Go´mez-Jarabo, G. & Rubia, F. J. (2001). An early electrophysiological sign of semantic processing in basal extrastriate areas. *Psychophysiology, 38*, 114– 125.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval. *Applied Cognitive Psychology, 14*, S127-S144.

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *30,* 605-614.

Misra, M., & Holcomb, P. J. (2003). Event-related potential indices of masked repetition priming. *Psychophysiology, 40,* 115-130.

Morgan, S. T., Hansen, J. C., & Hillyard, S. A. (1996). Selective attention to stimulus location modulates the steady-state visual evoked potential. *Proceedings of the National Academy of Sciences of the United States of America, 93,* 4770–4774.

Mueller, M. M., & Hillyard, S. (2000). Concurrent recording of steadystate and transient event-related potentials as indices of visualspatial selective attention. *Clinical Neurophysiology, 111,* 1544 –1552.

Mueller, M. M., Teder-Salejarvi, W., & Hillyard, S. A. (1998). The time course of cortical facilitation during cued shifts of spatial attention. *Nature Neuroscience, 1,* 631-634.

Nobre, A. C. (2004). Probing the flexibility of attentional orienting in the human brain. In M., Posner (Ed.), *Cognitive neuroscience of attention* (pp 157–179). New York: Guilford.

Nobre, A. C., & McCarthy, G. (1994). Language-related ERPs: scalp distributions and modulations by word type and semantic priming. *Journal of Cognitive of Neuroscience, 6,* 233-255.

Onton, J., Westerfield, M., Townsend, J., & Makeig, S. (2006). Imaging human EEG dynamics using independent component analysis. *Neurosci Biobehav Rev, 30,* 808-822.

Regan, D. (1989). *Human brain electrophysiology:Evoked potentials and evoked magnetic fields in science and medicine*. New York: Elsevier.

Schweinberger, S. R., Pickering, E. C., Burton, A. M., & Kaufmann, J. M. (2002). Human brain potential correlates of repetition priming in face and name recognition. *Neuropsychologia, 40*, 2057-2073.

Scullin, M.K., Einstein, G.O., & McDaniel, M.A. (2009). Evidence for spontaneous retrieval of suspended but not finished prospective memories. *Memory & Cognition, 37,* 425-433.

Simons, J. S., Scholvinck, M. L., Gilbert, S. J., Frith, C. D., & Burgess, P. W. (2006). Differential components of prospective memory? Evidence from fMRI. *Neuropsychologia, 44,* 1388-1397.

Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory:

Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 29,* 347-361.

Smith, R. E., & Bayen, U. J. (2004). A multinomial model of event-based prospective memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30,* 756-777.

Smith, R. E., & Bayen, U. J. (2005). The effects of working memory resource availability on prospective memory: A formal modeling approach. *Experimental Psychology, 52,* 243-256.

Smith, R. E., Hunt, R. R., McVay, J. C., & McConnell, M. D. (2007). The cost of event-based prospective memory: Salient target events. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 33,* 734-746.

Tenke, C. E., & Kayser, J. (2001). A convenient method for detecting electrolyte bridges in multichannel electroencephalogram and event-related potential recordings. *Clinical Neurophysiology, 112,* 545-550.

Tulving, E. & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80,* 352-373.

West, R. (2007). The influence of strategic monitoring on the neural correlates of prospective memory. *Memory & Cognition, 35,* 1034-1046.

West, R., Bowry, R., & Krompinger, J. (2006). The effects of working memory demands on the neural correlates of prospective memory. *Neuropsychologia, 44,* 197-207.

West, R., & Krompinger, J. (2005). Neural correlates of prospective and retrospective memory. *Neuropsychologia, 43,* 418-433.

West, R., McNerney, M. W., & Travers, S. (2007). Gone but not forgotten: the effects of cancelled intentions on the neural correlates of prospective memory. *International Journal of Psychophysiology, 64,* 215-225.

West, R., & Wymbs, N. (2004). Is detecting prospective cues the same as selecting targets? An ERP study. *Cognitive Affective Behavioral Neuroscience, 4,* 354-363.

Wilson, G. F., & O'Donnell, R. D. (1986). Steady-state evoked responses: Correlations with human cognition. *Psychophysiology,* 23, 57–61.

Yvert, B., Crouzeix, A., Bertrand, O., Seither-Preisler, A., & Pantev, C. (2001). Multiple supratemporal sources of magnetic and electric auditory evoked middle latency components in humans. Cerebral Cortex, 11, 1047-

FOOTNOTES

[1] Cue interference did not significantly differ between groups *t* (22) = -.20, *p* = .84, replicating previous work demonstrating that detecting specific and categorical cues interferes with word processing to the same extent (Marsh et al., 2003).

[2] The finding that noticing of specific and categorical cues was supported by a different neural mechanism may not simply be due to categorical information being accessed at a later stage of processing. In categorization tasks using pictures, ERPs have been found to dissociate between category type around 150 ms post-stimulus, and this dissociation was correlated with task performance (VanRullen & Thorpe, 2001). Thus, access to categorical information that influences behavioral performance can occur as early as 150 ms post-stimulus. Additionally, with regard to word processing, ERPs have been found to dissociate between different types of categories around 250 ms post-stimulus (Hinojosa et al., 2001; Martin-Loeches et al., 2001). Thus, the activity from 350-450 ms dissociating categorical cues and words in the current task was not simply the lower bound for access to categorical information.